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The Improvement of Prescription Dispensing Efficiency and Accuracy by Intelligent Pharmacy

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Abstract: Intelligent pharmacy systems are increasingly adopted to address delays, workload pressure, and avoidable dispensing errors in modern pharmaceutical services. This study evaluates pharmacist perceptions of how intelligent pharmacy technologies influence prescription dispensing efficiency, dispensing accuracy, medication safety, work experience, and implementation barriers. A quantitative cross-sectional survey was conducted among 50 pharmacists working in tertiary hospital pharmacies, community medical institution pharmacies, and chain retail pharmacies that had implemented intelligent pharmacy technologies. The questionnaire measured demographic characteristics and 15 indicators related to system speed, workflow design, patient waiting time, inventory management, prescription review, data entry, professional role transformation, training burden, cost, and system compatibility. Descriptive statistics were used to summarize means, standard deviations, and categorical distributions. The results show an overall positive perception of intelligent pharmacy applications (overall M = 3.42, SD = 1.34). The strongest perceived benefits were reduced patient waiting time (M = 3.70), greater focus on clinical guidance rather than manual dispensing (M = 3.70), improved prescription review for error reduction (M = 3.56), and improved work convenience and satisfaction (M = 3.54). However, equipment speed, workflow design, drug recognition, and data entry accuracy received only neutral evaluations, indicating that technology adoption alone does not guarantee full operational optimization. System complexity, maintenance cost, and platform incompatibility remained important constraints. The findings suggest that intelligent pharmacy systems should be implemented as socio-technical systems requiring workflow redesign, standardized operating procedures, system integration, and tiered pharmacist training. The study contributes practice-oriented evidence for pharmacy managers seeking to improve service quality while preserving the clinical and human-centered value of pharmacists.

Keywords: Intelligent pharmacy, prescription dispensing, medication safety, pharmacy automation, pharmacists

I. INTRODUCTION

Prescription dispensing is a high-volume and safety-sensitive component of pharmaceutical service. Pharmacists are required to review prescriptions, verify drug names and specifications, check dosage and contraindications, complete inventory operations, dispense medications, and provide patient counseling within limited time. When prescription volume increases, manual workflows can intensify workload, extend patient waiting time, and create conditions for avoidable medication errors. Medication safety has therefore become a major international concern, and global patient-safety frameworks emphasize the need for safer medication-use systems, stronger process control, and active participation of healthcare professionals in error prevention [1], [2].

Intelligent pharmacy systems have been introduced as one response to these pressures. In this paper, intelligent pharmacy refers to a pharmacy service model that integrates electronic prescription management, automated or semi-automated dispensing, drug identification, inventory monitoring, traceability, prescription review, and data-supported management. The promise of this model is not simply mechanical substitution. A mature intelligent pharmacy links dispensing devices with prescription platforms, inventory databases, medication review systems, and patient-facing service pathways so that prescription receipt, checking, dispensing, verification, and delivery can be more standardized and traceable.

Evidence from pharmacy automation and automated medication-distribution research suggests that such technologies may reduce dispensing time, support inventory control, and prevent some medication-related errors [3]-[6]. At the same time, the literature also shows that the benefits of automation are heterogeneous. Automated dispensing cabinets, barcode systems, inventory platforms, and prescription review tools do not operate in isolation from people and workflows. Human factors, alert design, interface usability, system maintenance, and pharmacist verification remain decisive for safety [7]. Technology acceptance research further indicates that perceived usefulness, ease of use, facilitating conditions, and professional expectations influence whether users integrate a system into daily practice [8]-[10].

These considerations are important because many studies and practice reports describe intelligent pharmacy as though it automatically improves efficiency and accuracy once equipment is installed. Such claims are difficult to justify when the available evidence is perception-based, cross-sectional, or limited to a small number of institutions. Objective operational indicators such as dispensing time, prescription volume per hour, actual error rates, system downtime, and pre-post comparisons are necessary to demonstrate measurable performance improvement. Where such indicators are unavailable, findings should be positioned more cautiously as perceived benefits and perceived implementation constraints.

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The present study addresses this issue by revising the research position from a claim about the improvement of dispensing efficiency and accuracy to an exploratory description of pharmacists' perceptions. The study asks three questions: (1) Which aspects of intelligent pharmacy systems are perceived most positively by pharmacists? (2) Which system functions and implementation conditions are perceived as weak or constraining? (3) How can the findings be interpreted through a socio-technical framework that links technical, managerial, and human factors? The contribution of the study is therefore practice-oriented rather than causal. It provides a structured account of how pharmacists in several pharmacy settings perceived intelligent pharmacy implementation and identifies conditions that should be addressed before stronger claims about effectiveness can be made.

II. LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

A. Pharmacy automation and dispensing performance

Research on pharmacy automation has moved from single-device efficiency toward integrated medication-management systems. Automated dispensing cabinets, robotic storage systems, barcode-supported verification, and electronic prescription review are designed to reduce repetitive manual work and improve process traceability. Systematic reviews report that in-hospital pharmacy automation is often associated with shorter dispensing time, fewer distribution errors, and potential cost savings in selected settings [3], [4]. Intervention studies in intensive care and inpatient environments also suggest that automated drug dispensing systems can reduce selected medication errors when they are well integrated into the medication-use process [5].

Nevertheless, automation outcomes vary by context. A device that improves one step of dispensing may not improve the entire prescription pathway if prescription entry, drug identification, inventory synchronization, pharmacist verification, and patient delivery remain poorly coordinated. The effect of automation is therefore mediated by workflow design, information interoperability, and exception management. Intelligent pharmacy research in China has similarly emphasized multi-device coordination, drug information integration, RFID- or IoT-supported monitoring, and unattended service models as important development directions [11]-[16]. These studies support the value of intelligent pharmacy development while also showing that implementation quality, not technology ownership alone, determines perceived performance.

B. Medication safety, human factors, and pharmacist verification

Medication safety is the second foundation of intelligent pharmacy research. Manual dispensing can be affected by look-alike or sound-alike drug names, similar packaging, fatigue, interruptions, incomplete information, and peak-period workload. Intelligent pharmacy systems attempt to reduce these vulnerabilities through prescription review, barcode or RFID verification, automatic sorting, inventory matching, and traceable records. Barcode technology has been shown to improve medication-administration safety in hospital settings when embedded in a closed process [6]. Similar logic applies to pharmacy dispensing: the value of a digital check depends on whether pharmacists understand, trust, verify, and respond appropriately to system outputs.

Human factors scholarship warns that technology can prevent some errors while creating new risks through alert fatigue, over-reliance on system prompts, poorly designed interfaces, and unclear responsibility boundaries [7]. In intelligent pharmacy practice, safety cannot be delegated entirely to the machine. Pharmacists remain responsible for professional judgment, final verification, counseling, and the management of exceptions such as prescription ambiguity, drug substitution, system downtime, and patient-specific risk. Consequently, perceived accuracy and medication safety should be evaluated as socio-technical outcomes produced by both system design and human practice.

C. Pharmacist role transformation and technology acceptance

Intelligent pharmacy implementation also changes pharmacists' work experience. By reducing repetitive drug-searching and sorting tasks, automated systems may allow pharmacists to spend more time on prescription appropriateness review, patient counseling, adverse reaction monitoring, medication adherence support, and data-based inventory management. This role transformation is an important justification for intelligent pharmacy development. However, professional transformation is not automatic. It depends on staffing models, performance indicators, training resources, system usability, and the extent to which organizations recognize clinical and advisory work as part of pharmacists' responsibilities.

Technology acceptance theory helps explain why pharmacists may respond unevenly to intelligent systems. The Technology Acceptance Model emphasizes perceived usefulness and ease of use [9], while the Unified Theory of Acceptance and Use of Technology extends this logic to performance expectancy, effort expectancy, social influence, and facilitating conditions [10]. In pharmacy settings, these concepts translate into concrete questions: Does the system make work more efficient? Is it easy to learn? Does it reduce or relocate workload? Are managers and colleagues supportive? Are training and technical support adequate? A perception survey cannot prove actual efficiency improvement, but it can reveal whether frontline users regard the system as useful, burdensome, risky, or professionally enabling.

D. Conceptual framework and operational mapping

The conceptual framework of this study uses an input-process-output logic. Inputs include technical factors, managerial factors, and human factors. Technical factors refer to device speed, drug recognition, data accuracy, compatibility, and digital infrastructure. Managerial factors refer to workflow design, prescription review procedures, inventory management, cost, maintenance, and SOPs. Human factors refer to training, workload, acceptance, satisfaction, and professional role perception. These inputs shape the prescription dispensing process, including prescription receipt, review, drug identification, dispensing, pharmacist verification, medication delivery, and patient counseling. Outputs include perceived patient waiting time, perceived dispensing accuracy, perceived medication safety, pharmacist satisfaction, and perceived professional development.

Table I operationalizes this framework by mapping questionnaire items to the framework dimensions. This mapping was added in response to the need for a tighter connection between theory, measurement, results, and discussion.

TABLE I
Operationalization of the Socio-Technical Framework

Framework dimension	Related questionnaire items	Analytic purpose
Technical factors	Equipment speed; drug recognition; data entry accuracy; system compatibility	Identify whether hardware and information functions are perceived as reliable and usable.
Managerial factors	Workflow design; inventory management; prescription review; construction and maintenance cost	Assess whether organizational processes and SOPs support technology use.
Human factors	Training need; learning burden; work convenience; satisfaction; role transformation	Evaluate user experience, adaptation pressure, and professional role change.
Perceived outcomes	Patient waiting time; manpower occupancy; perceived error reduction; career development	Summarize perceived service and professional effects without claiming causality.

III. METHODS

A. Design

This study used a quantitative, cross-sectional, descriptive survey design. The design was selected because the objective was to summarize pharmacists' perceptions of intelligent pharmacy systems at a defined point in time. Cross-sectional survey methods are suitable for describing current practice and identifying response patterns when experimental manipulation or pre-post operational comparison is not available [20], [21]. The study did not aim to establish causal effects. All results are therefore interpreted as pharmacist-reported perceptions rather than objective proof that intelligent pharmacy systems improved dispensing efficiency or accuracy.

The manuscript uses descriptive statistics only. This decision is important methodologically because the available dataset consisted of summarized counts, means, and standard deviations rather than raw respondent-level data. Without raw data, it was not appropriate to perform t tests, ANOVA, regression, exploratory factor analysis, or reliability testing. The paper therefore avoids inferential claims and emphasizes transparent, conservative interpretation.

B. Setting, participants, and recruitment

The study population consisted of pharmacists working in pharmacy settings where intelligent pharmacy technologies had already been implemented. The final valid sample included 50 pharmacists from three categories of pharmacy practice: tertiary comprehensive hospital pharmacies, community medical institution pharmacies, and chain retail pharmacies. Participants were selected purposively because the study required respondents with direct exposure to intelligent pharmacy functions. Inclusion criteria were current employment in a pharmacy-related position, direct involvement in prescription review, dispensing, pharmacy management, or system operation, at least six months of exposure to intelligent pharmacy technology, and voluntary consent to participate. Probationary personnel, interns, and incomplete questionnaires were excluded.

The available dataset recorded pharmacy type and size but did not retain institution identifiers, number of participating institutions, geographic region, or a fixed sampling denominator. Consequently, a formal response rate could not be calculated. This reporting limitation reduces external validity and is acknowledged in the limitations section. The study should therefore be treated as an exploratory perception survey rather than as a representative evaluation of all intelligent pharmacies.

C. Intelligent pharmacy technologies included

Participants were not required to use an identical product model or a single standardized system. The questionnaire targeted common functional categories of intelligent pharmacy implementation, including automated or semi-automated dispensing devices, electronic prescription review, drug recognition or barcode/RFID-supported verification, inventory management platforms, data entry and confirmation functions, and system integration with existing information platforms. This approach allowed respondents from different pharmacy settings to evaluate comparable functions, but it also means that differences among device brands, software versions, and implementation maturity could not be analyzed.

D. Questionnaire development and measurement validity

The questionnaire included demographic items and 15 Likert-scale indicators. The items were self-developed from the study objectives, the conceptual framework, and literature on pharmacy automation, medication safety, health information systems, and technology acceptance [3]-[10], [11]-[18]. Items were grouped conceptually into four domains: perceived dispensing efficiency, perceived medication safety and accuracy, pharmacist work experience and role transformation, and implementation barriers. Response options ranged from 1 = strongly disagree to 5 = strongly agree. Interpretation intervals were defined as 4.20-5.00 = strongly agree, 3.40-4.19 = agree, 2.60-3.39 = neutral, 1.80-2.59 = disagree, and 1.00-1.79 = strongly disagree.

Because the original dataset did not include item-level responses or a separate validation dataset, psychometric validation was limited. Cronbach's alpha, subscale reliability, and exploratory factor analysis could not be calculated. For that reason, the study reports item-level means and standard deviations rather than treating the questionnaire as a validated scale. Item

12 was negatively worded: 'Learning and mastering new intelligent pharmacy systems is a burden for pharmacists.' It was interpreted as a perceived barrier item. When considering overall positive perception, Item 12 should be reverse-scored; however, because raw data were unavailable, the paper does not report a validated composite score. This cautious approach directly addresses the limitation that questionnaire validity and reliability evidence remain insufficient.

E. Data collection and ethics

Data were collected through a structured questionnaire. Respondents were informed that participation was voluntary, that results would be reported at the aggregate level, and that no personal identifiers or patient data would be reported. Completed questionnaires were screened for completeness and logical consistency before analysis. The final analytic sample contained 50 valid responses.

The study used anonymous professional perception data and did not collect patient information. The available source materials did not provide a formal ethics approval number or review-board name. This should be clarified by the authors before journal submission if the target journal requires institutional ethics documentation. In the present manuscript, ethical reporting is limited to voluntary participation, anonymity, aggregate reporting, and protection of respondent confidentiality.

F. Data analysis

Descriptive statistics were used to summarize categorical variables, item means, and standard deviations. Frequencies and percentages were used for demographic and organizational characteristics. Mean scores were used to describe the direction of pharmacist perceptions, and standard deviations were used to indicate dispersion among respondents. Particular attention was paid to neutral items and items with large standard deviations because such results may signal uneven implementation, differences among system types, or inconsistent user experience. No inferential analysis was conducted.

IV. RESULTS

A. Respondent characteristics

Table II presents the demographic and organizational characteristics of the 50 respondents. The sample was composed entirely of pharmacists working in settings where intelligent pharmacy technologies had been implemented. The largest age groups were 26-35 years (38.0%) and 36-45 years (30.0%), suggesting that most respondents were early- to mid-career pharmacists. Chain retail pharmacies accounted for 52.0% of the sample, while tertiary comprehensive hospital pharmacies and community medical institution pharmacies each accounted for 24.0%. Medium-sized pharmacies represented the largest organizational group (64.0%). Pharmacists with 4-6 years of work experience formed the largest experience category (38.0%).

TABLE II

Demographic and Organizational Characteristics of Respondents (N = 50)

Variable	Category	N	%
Age	18-25 years	9	18.0
Age	26-35 years	19	38.0
Age	36-45 years	15	30.0
Age	46 years and above	7	14.0
Pharmacy type	Tertiary comprehensive hospital pharmacy	12	24.0
Pharmacy type	Community medical institution pharmacy	12	24.0
Pharmacy type	Chain retail pharmacy	26	52.0
Pharmacy size	Small pharmacy (less than 10 staff)	7	14.0
Pharmacy size	Medium pharmacy (10-50 staff)	32	64.0
Pharmacy size	Large pharmacy (more than 50 staff)	11	22.0
Use of intelligent devices	Yes	50	100.0
Use of intelligent devices	No	0	0.0
Work experience	Less than 1 year	7	14.0
Work experience	1-3 years	9	18.0
Work experience	4-6 years	19	38.0
Work experience	7-10 years	9	18.0
Work experience	More than 10 years	6	12.0

B. Scoring interpretation and item direction

Table III clarifies item direction. Items measuring perceived benefits are interpreted as more positive when their mean scores are higher. Items measuring barriers are interpreted differently: higher scores indicate stronger perceived constraints rather than better performance. Item 12 is negatively worded and should be reverse-scored if included in a positive composite index. Because raw data were unavailable, no validated composite index is reported.

TABLE III

Measurement Domains and Interpretation of Item Direction

Domain	Item numbers	Direction	Interpretation note
Dispensing efficiency	1-4	Positive	Higher scores indicate stronger perceived efficiency-related benefits.

Domain	Item numbers	Direction	Interpretation note
Medication safety and accuracy	5-8	Positive	Higher scores indicate stronger perceived safety or accuracy support.
Work experience and role transformation	9, 11, 13	Positive	Higher scores indicate stronger perceived professional or convenience benefits.
Training and implementation barriers	10, 14, 15	Barrier	Higher scores indicate stronger perceived training, cost, or compatibility constraints.
Learning burden	12	Negative/barrier	Mean is interpreted as perceived burden; reverse coding is required for positive composite scoring.

C. Perceived performance of intelligent pharmacy systems

Table IV reports the mean scores, standard deviations, and interpretation labels for the 15 survey indicators. The overall unadjusted item mean was 3.42 (SD = 1.34), which falls in the agreement range. However, this value should not be interpreted as a validated total scale because the questionnaire has not been psychometrically validated and because several items measure barriers rather than benefits. If the negatively worded Item 12 is reverse-scored at the item-mean level, the adjusted descriptive average of the 15 item means would be approximately 3.49. This adjusted value is reported only for transparency and not as an inferential result.

TABLE IV

Questionnaire Results on Intelligent Pharmacy Applications

No.	Indicator	Mean	SD	Interpretation
1	The operating speed of intelligent pharmacy devices has significantly improved the efficiency of prescription dispensing.	3.34	1.38	Neutral
2	The system operation process design of the intelligent pharmacy is reasonable, reducing dispensing time.	3.36	1.41	Neutral
3	After using intelligent pharmacies, patient waiting time has significantly reduced.	3.70	1.36	Agree
4	Intelligent pharmacy devices have reduced the manpower occupancy rate of pharmacists in dispensing work.	3.50	1.36	Agree
5	The drug recognition system of intelligent pharmacies is effective in preventing errors.	3.38	1.25	Neutral
6	The inventory management mechanism of intelligent pharmacies has improved the accuracy of drug supply.	3.52	1.43	Agree
7	The prescription review process of intelligent pharmacies helps reduce dispensing errors.	3.56	1.20	Agree
8	Pharmacists' data entry accuracy has improved when entering or confirming prescription information.	3.26	1.31	Neutral
9	The application of intelligent pharmacies has made pharmacists' work more focused on clinical guidance rather than manual operations.	3.70	1.33	Agree
10	The operational complexity of intelligent pharmacy systems is high, requiring more training for pharmacists.	3.56	1.40	Agree
11	The introduction of intelligent pharmacies provides more career development opportunities for pharmacists.	3.44	1.37	Agree
12	Learning and mastering new intelligent pharmacy systems is a burden for pharmacists.	2.46	1.45	Disagree
13	Intelligent pharmacies have improved the convenience and satisfaction of pharmacists' work.	3.54	1.27	Agree
14	The high cost of equipment construction and maintenance has limited the promotion of intelligent pharmacies.	3.42	1.30	Agree
15	The incompatibility between the system and existing platforms has affected the effectiveness of intelligent pharmacy applications.	3.54	1.31	Agree
Overall	Unadjusted descriptive item mean	3.42	1.34	Agree

Note. Scale intervals: 4.20-5.00 = strongly agree; 3.40-4.19 = agree; 2.60-3.39 = neutral; 1.80-2.59 = disagree; 1.00-1.79 = strongly disagree. For Items 10, 14, and 15, higher values indicate stronger perceived barriers. Item 12 is negatively worded and should be reverse-scored before any positive composite score is calculated.

D. Item-level interpretation

The most positive perceived outcomes were patient waiting time (M = 3.70, SD = 1.36) and the shift from manual operations toward clinical guidance (M = 3.70, SD = 1.33). Respondents also agreed that prescription review helped reduce dispensing errors (M = 3.56, SD = 1.20), that intelligent pharmacies improved work convenience and satisfaction (M = 3.54, SD = 1.27), and that inventory management improved drug supply accuracy (M = 3.52, SD = 1.43). These results suggest that respondents perceived benefits most clearly at the level of patient-facing service, structured prescription review, inventory control, and professional role reallocation.

Neutral ratings appeared for equipment operating speed (M = 3.34, SD = 1.38), workflow design (M = 3.36, SD = 1.41), drug recognition effectiveness (M = 3.38, SD = 1.25), and data entry accuracy (M = 3.26, SD = 1.31). These neutral findings are analytically important because they indicate that technology implementation did not produce uniformly positive user perceptions. Internal workflow design and human-system interaction were less strongly endorsed than patient waiting time and clinical role transformation.

Barrier items also require careful interpretation. Respondents agreed that operational complexity required more training (M = 3.56, SD = 1.40), that cost limited promotion (M = 3.42, SD = 1.30), and that system incompatibility affected application effectiveness (M = 3.54, SD = 1.31). At the same time, they disagreed that learning and mastering intelligent pharmacy systems was a burden (M = 2.46, SD = 1.45). This combination suggests that pharmacists recognized the need for training but did not necessarily reject the learning process. The relatively large standard deviations across many items indicate substantial variation in experience, possibly reflecting differences in pharmacy type, system maturity, training quality, or workflow integration.

V. DISCUSSION

This revised analysis provides a more defensible interpretation of the study. The findings do not demonstrate that intelligent pharmacy systems objectively improved dispensing efficiency or accuracy. Instead, they show that surveyed pharmacists generally perceived intelligent pharmacy applications positively, while also identifying uneven benefits and important implementation barriers. This distinction is essential for scientific accuracy. A perception survey can reveal frontline experience and practical concerns, but it cannot replace operational data such as actual waiting time, prescription throughput, error rates, downtime, or before-after comparisons.

The strongest perceived benefit was shorter patient waiting time. This result is plausible because intelligent pharmacy systems can reduce visible delays by digitizing prescription flow, automating certain dispensing steps, and improving queue management. However, the neutral ratings for equipment speed and workflow design show that pharmacists did not uniformly experience the internal dispensing process as optimized. The apparent contrast between patient-facing benefit and workflow-level neutrality suggests that partial efficiency gains may occur even when staff continue to encounter fragmented procedures, manual corrections, or repeated verification tasks. Pharmacy managers should therefore avoid assuming that patient waiting-time improvement alone proves workflow excellence.

Medication safety findings also require a socio-technical interpretation. Prescription review and inventory management were perceived positively because they provide structured checks and reduce variability in drug supply. By contrast, drug recognition and data entry accuracy received neutral ratings. These functions depend heavily on barcode quality, system configuration, interface design, drug dictionary maintenance, and staff operation. International medication-safety research shows that automation and barcode-supported systems can prevent selected errors, but the effectiveness of these technologies depends on their integration into a reliable and human-centered workflow [5]-[7]. Intelligent pharmacy safety should therefore involve multiple layers: automated recognition, prescription review, pharmacist verification, traceable records, regular audit of alerts and overrides, and clear exception-handling procedures.

The role-transformation findings are particularly meaningful. Respondents perceived that intelligent pharmacy systems allowed pharmacists to focus more on clinical guidance rather than manual dispensing. This result is consistent with the professional movement from product-centered dispensing toward patient-centered pharmaceutical care. Yet the shift will remain limited if pharmacy organizations continue to evaluate pharmacists mainly by the volume of prescriptions dispensed. Intelligent pharmacy implementation should be accompanied by revised job descriptions, workload allocation, performance indicators, and training pathways that recognize prescription appropriateness review, patient counseling, medication safety monitoring, system supervision, and data-based inventory management as legitimate professional outputs.

Training emerged as both a requirement and a manageable challenge. Respondents agreed that operational complexity required more training, but they did not agree that learning the system was a burden. This suggests that pharmacists may accept additional technological learning when the system is perceived to support professional value. Training should not be limited to device operation. It should include workflow logic, data entry standards, alert interpretation, error reporting, downtime procedures, privacy protection, patient communication, and responsibility boundaries between the system and the pharmacist. Tiered training is advisable: new users require basic operation and troubleshooting; senior pharmacists require quality control and exception management; managers require data interpretation, performance monitoring, and cost-benefit evaluation.

Cost and compatibility were also major perceived constraints. Intelligent pharmacy systems require investment in hardware, software, maintenance, space redesign, staff training, and information security. Smaller pharmacies may need modular implementation rather than full automation. Larger hospitals may face the more complex problem of integrating prescription systems, electronic medical records, inventory systems, automated dispensing devices, and patient-facing platforms. Incompatibility can generate duplicate data entry, inconsistent inventory records, delayed exception handling, and reduced user trust. Interoperability should therefore be a pre-implementation design criterion rather than a technical afterthought. Shared drug dictionaries, standardized coding, interface testing, and real-time inventory synchronization should be included in procurement and acceptance criteria.

The study's conceptual contribution lies in clarifying the conditions under which pharmacists perceive intelligent pharmacy systems as useful. Positive perception was strongest when technology visibly improved service experience or professional role opportunity. Perception was weaker when respondents evaluated the fine mechanics of device speed, recognition accuracy, data entry, or workflow design. This pattern supports the input-process-output framework.

Technical factors, managerial factors, and human factors do not contribute separately; they interact in the prescription dispensing process. Intelligent pharmacy performance should therefore be evaluated as a socio-technical system rather than as a single hardware intervention.

VI. PRACTICAL IMPLICATIONS

First, pharmacies should redesign SOPs around intelligent workflows rather than transferring manual procedures into automated environments. SOPs should define prescription intake, review, automated dispensing, pharmacist verification, exception handling, final release, patient counseling, and record retention. Clear responsibility boundaries can reduce duplicated work and improve consistency.

Second, implementation should be supported by role-based pharmacist training. Basic users need device operation and common troubleshooting; experienced pharmacists need alert review, data checking, and risk management; pharmacy managers need system-data interpretation, staffing analysis, inventory planning, and performance evaluation. Training should be continuous because intelligent pharmacy functions, drug databases, and platform interfaces change over time.

Third, information-system integration should be planned before deployment. Pharmacy departments, information departments, clinicians, and vendors should jointly define data standards, interface requirements, drug coding rules, maintenance procedures, and accountability for system updates. Without this foundation, intelligent pharmacy may create fragmented digital work rather than genuine process optimization.

Fourth, implementation should be scalable. Not all pharmacies need the same level of automation. Small and medium-sized pharmacies may begin with high-impact modules such as electronic prescription review, barcode verification, or inventory monitoring. Large institutions may adopt more complex closed-loop dispensing and analytics functions. Evaluation indicators should include objective measures such as average dispensing time, prescriptions processed per hour, waiting time records, dispensing error rate, inventory discrepancy rate, system downtime, manual interventions, and prescription review alerts.

Fifth, intelligent pharmacy evaluation should combine operational indicators with pharmacist and patient experience. Objective records are needed to determine actual performance, but user perceptions remain important because pharmacists encounter system limitations, workarounds, exception cases, and patient communication problems. A balanced evaluation system can prevent both uncritical technology optimism and excessive resistance to automation.

VII. LIMITATIONS AND FUTURE RESEARCH

Several limitations should be emphasized. First, the sample size was modest and the sampling strategy was purposive rather than random. The findings cannot be generalized to all intelligent pharmacies. Second, the study relied on pharmacist perceptions rather than independently verified operational indicators. Perceptions are useful for understanding user experience, but they cannot prove actual reductions in dispensing time or error rates. Third, the available dataset did not contain institution identifiers, geographic information, survey dates, or a response denominator. As a result, the number of institutions, regional distribution, and response rate could not be reported.

Fourth, the available data were summarized rather than respondent-level. Reliability statistics, factor analysis, subgroup analysis, correlations, and regression could not be calculated. Fifth, the questionnaire was self-developed and lacked formal validation evidence. Its results should therefore be interpreted item by item rather than as a validated multidimensional scale. Sixth, the study did not distinguish among specific intelligent pharmacy technologies or product models. Automated dispensing devices, prescription review software, inventory platforms, barcode/RFID systems, and patient self-service devices may generate different benefits and barriers. Seventh, the cross-sectional design cannot show changes over time or establish causal effects.

Future research should use multi-site longitudinal designs and collect objective operational data before and after intelligent pharmacy implementation. Useful indicators include average dispensing time, prescriptions processed per hour, patient waiting time, dispensing error rate, inventory discrepancy rate, equipment downtime, number of manual interventions, prescription review alert volume, override rates, pharmacist workload, patient satisfaction, and pharmacist satisfaction. Larger studies should also calculate scale reliability, conduct exploratory or confirmatory factor analysis, and test relationships among technical, managerial, and human factors. Qualitative interviews could further explain why some functions are perceived positively while others remain neutral. Mixed-methods designs would provide stronger evidence for both performance outcomes and implementation mechanisms.

VIII. CONCLUSION

This study examined pharmacists' perceptions of intelligent pharmacy systems through a cross-sectional survey of 50 pharmacists from tertiary comprehensive hospital pharmacies, community medical institution pharmacies, and chain retail pharmacies. The findings indicate generally positive perceptions, especially regarding patient waiting time, prescription review, inventory management, work convenience, and the shift from manual dispensing toward clinical guidance. However, the findings also show that perceived benefits were uneven. Equipment speed, workflow design, drug recognition, and data entry accuracy received only neutral evaluations, while training requirements, construction and maintenance cost, and platform incompatibility remained important constraints.

The central conclusion is therefore cautious: intelligent pharmacy systems were perceived by surveyed pharmacists as beneficial in several areas, but the study does not provide objective evidence that they directly improved dispensing efficiency or accuracy. Full performance improvement requires more than equipment adoption. It depends on workflow redesign, validated SOPs, interoperable information systems, pharmacist training, maintenance support, and human-centered service pathways. For pharmacy managers and policymakers, intelligent pharmacy should be treated as a socio-technical service model in which technology supports, but does not replace, professional judgment and patient-centered pharmaceutical care.

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